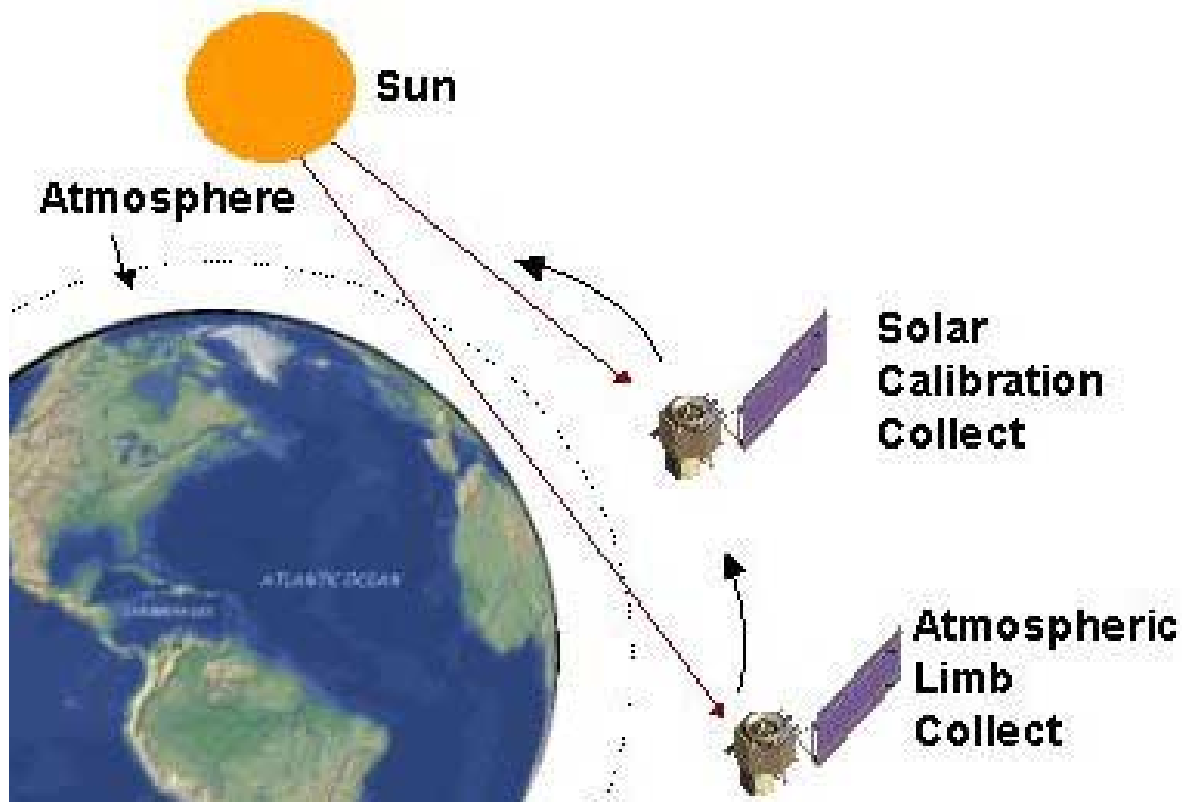# Hyperion On-Orbit Validation of Spectral Calibration using Atmospheric Lines and an On-board System

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Introduction

Hyperion Instrument

Spectral Calibration

On-Orbit Verification Technique

Comparison

Hyperion Image Overview

- *7.7 km swath width*

- *160 km swath length (time variable)*

- *30 meter spatial resolution*

- *10 nm spectral resolution*

- *200 radiometrically and spectrally calibrated continuous bands from 435 nm to 2400 nm*

- *Better than 6% absolute radiometric accuracy*

Solar Baffle

Spectrometer

Telescope

Cryocooler
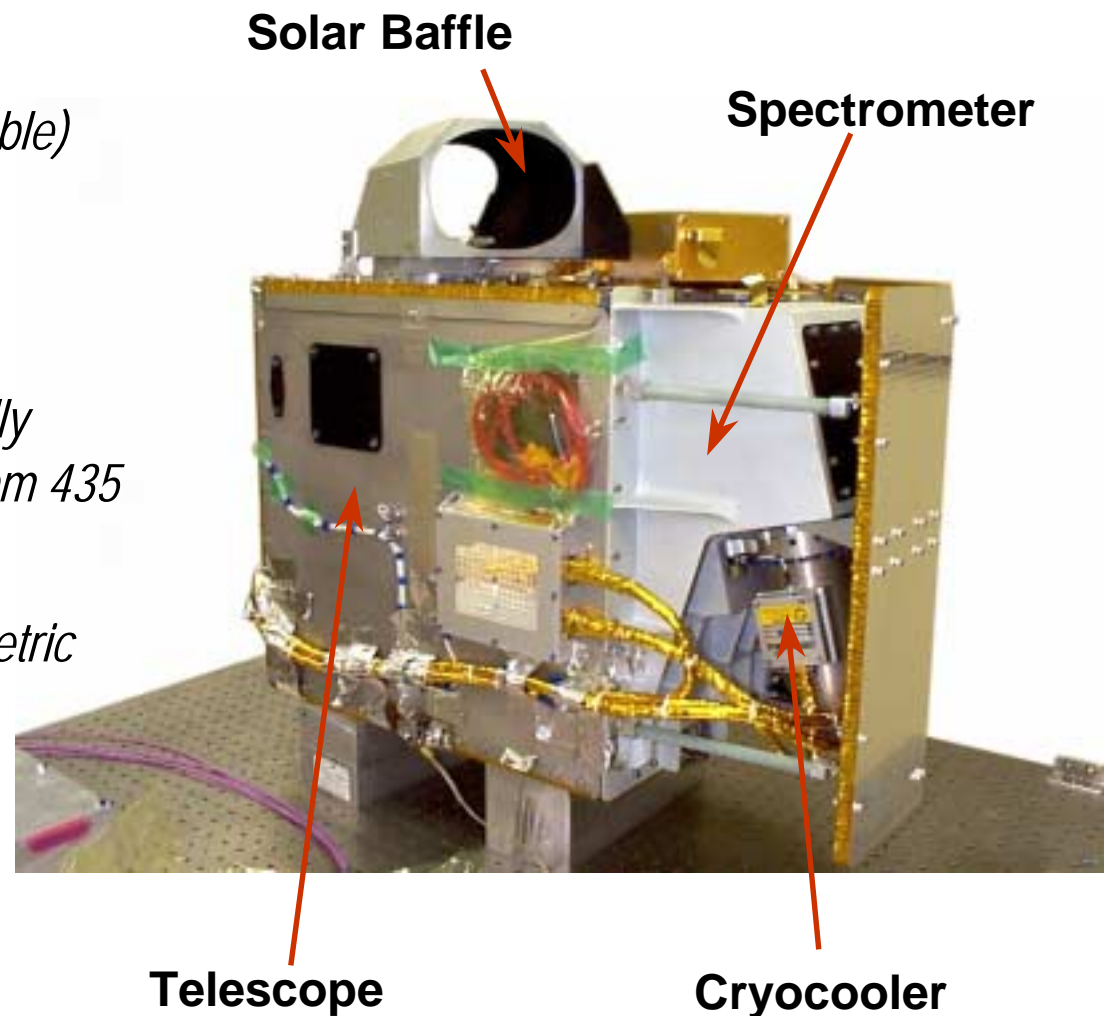
Hyperion Data Cube

Pushbroom configuration, entire swath width collected each frame sampled every 4.5 ms, or 223.4 frames/second.

Common fore-optics, dichroic filter reflects 400 nm to 1000 nm to the VNIR and transmits 900 nm to 2500 nm to the SWIR.
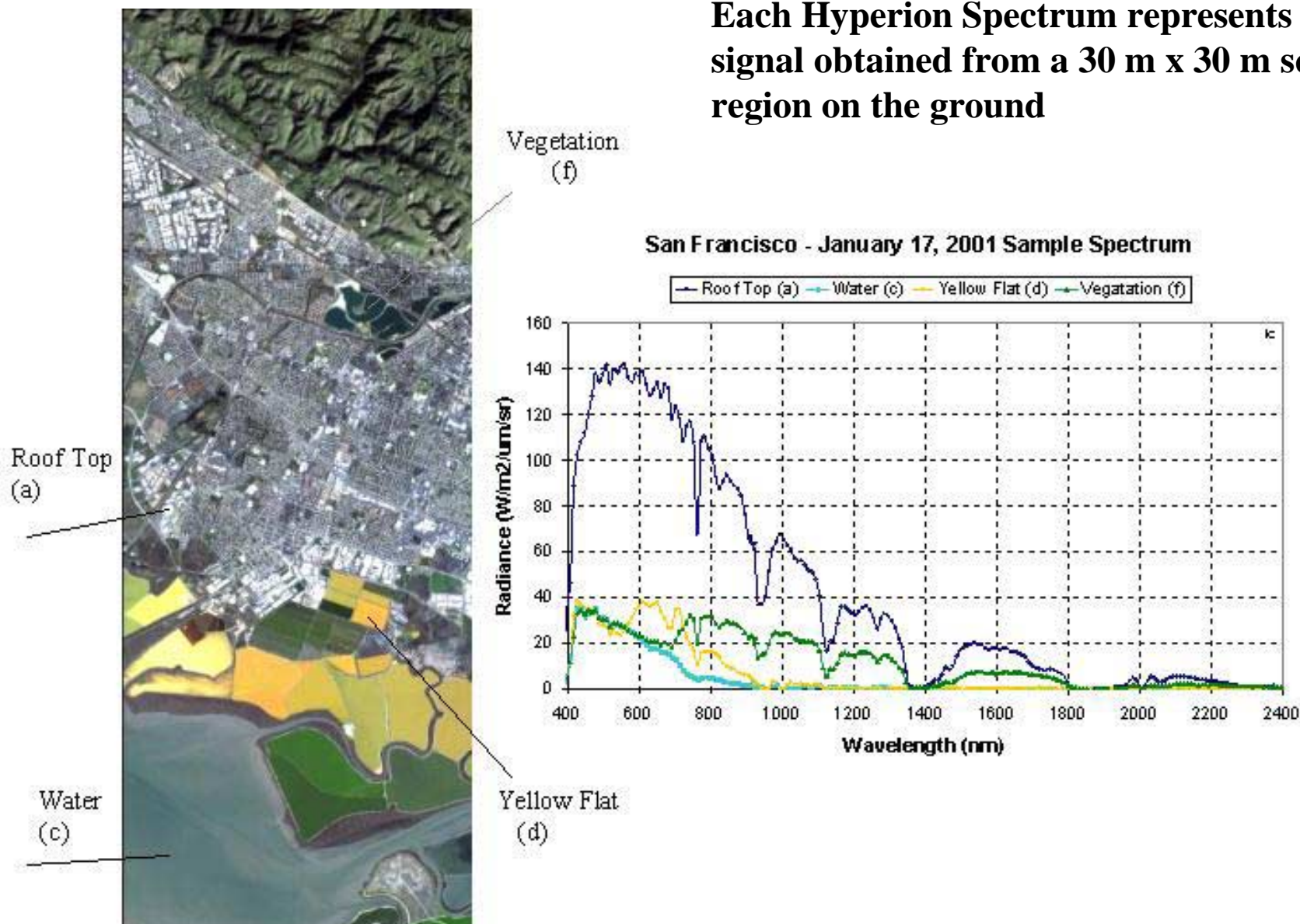
Gratings disperse light onto two focal planes

field of view
256 pixels

Time
6925
frames

spectral range
242 bands

field of view
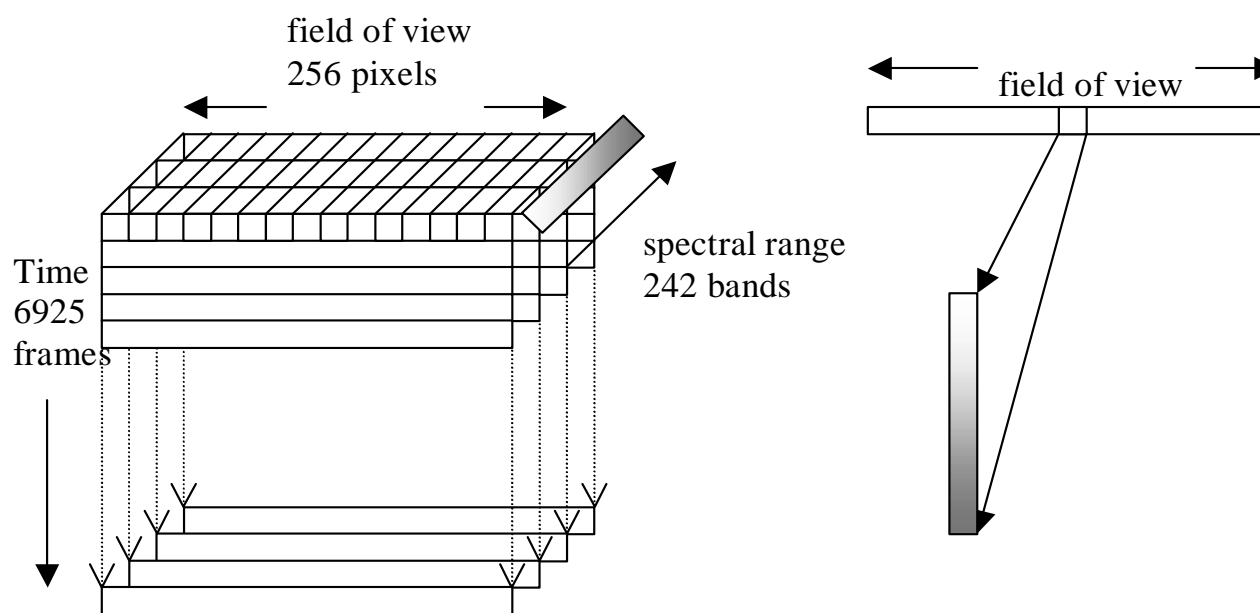
- *Produces a three dimensional data cube 256x6925x242 in 30 seconds!*

Samples of of Hyperion Spectra

Each Hyperion Spectrum represents the signal obtained from a 30 m x 30 m square region on the ground

Vegetation (f)

Roof Top (a)

Water (c)

Yellow Flat (d)

San Francisco - January 17, 2001 Sample Spectrum

Legend: Roof Top (a) — Water (c) — Yellow Flat (d) — Vegatation (f)

Y-axis: Radiance (W/m2/um/sr) — 0, 20, 40, 60, 80, 100, 120, 140, 160

X-axis: Wavelength (nm) — 400, 600, 800, 1000, 1200, 1400, 1600, 1800, 2000, 2200, 2400

Spectral Calibration Calibration

Defined by a center wavelength an assumed Gaussian full width half max

Band to band
center difference

Gaussian
FWHM
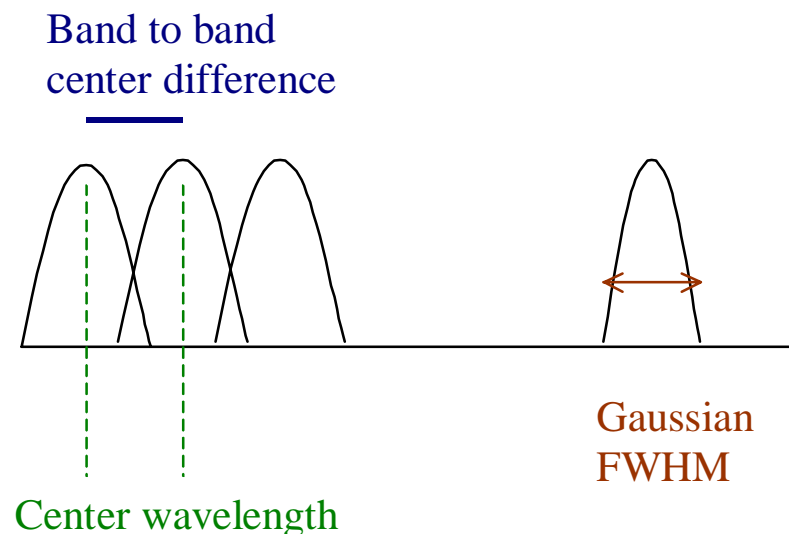
Center wavelength

Measured center wavelength and bandwidth at discrete locations on the focal plane, 20 VNIR locations, 25 SWIR locations.

Used to define a value for EVERY VNIR and SWIR pixel, 256 field-of-view locations and 242 spectral bands.

Contained in two ascii files SpectralL0_revA.1, BandwidthL0_revA.1 (_revA.1 because of file format change)
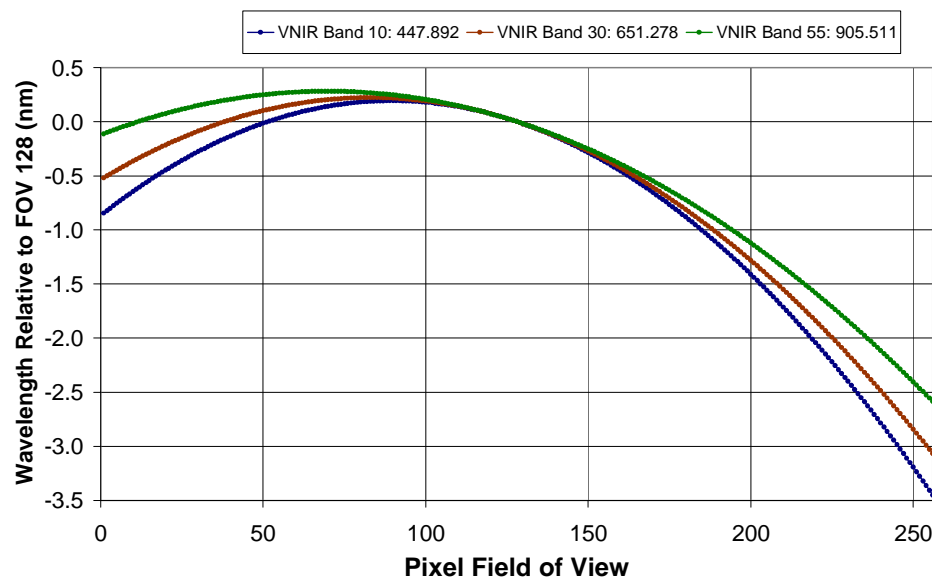
Characteristics of Spectral Calibration

Center wavelength and *Bandwidth* described by the assumed Gaussian
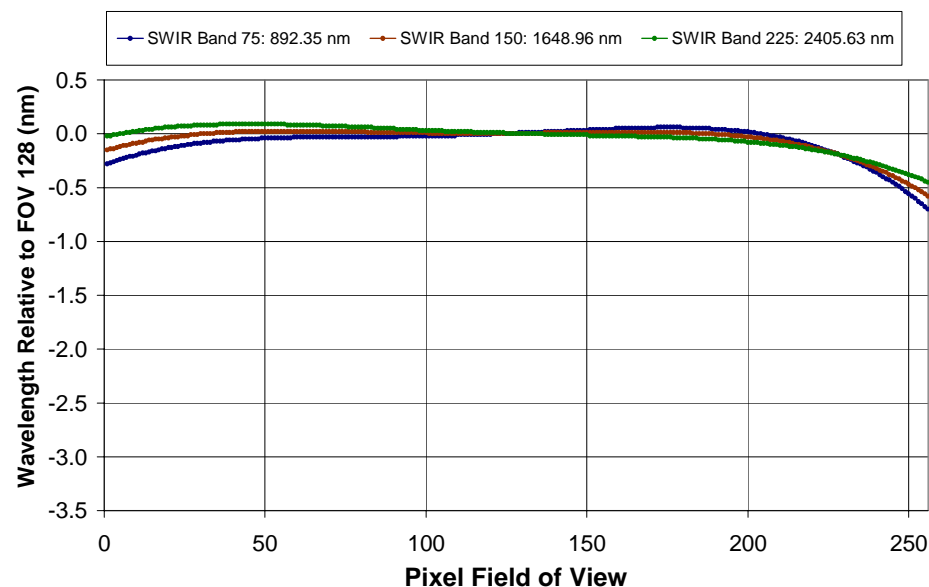
Dispersion which is nm spacing of spectral channels, Hyperion dispersion (~10nm/pixel) closely matches the bandwidth (10 nm)

Cross-track spectral error which is the maximum variation of the center wavelength across the field-of-view for a single spectral channel, 2.6-3.6 for VNIR and .40-.97 for SWIR. Example below.

VNIR Spectral Variation Across the Field of View

— VNIR Band 10: 447.892 — VNIR Band 30: 651.278 — VNIR Band 55: 905.511

SWIR Spectral Variation Across the Field of View

— SWIR Band 75: 892.35 nm — SWIR Band 150: 1648.96 nm — SWIR Band 225: 2405.63 nm

On-Orbit Spectral Calibration Verification

Goal

> *verify center wavelength for VNIR and SWIR*
>
> *verify cross-track spectral error*
>
> *verify dispersion*

Performed atmospheric Limb collect

> *collect of reference spectrum (atmosphere and diffuse reflectance)*
>
> *collect uniform across the field-of-view*
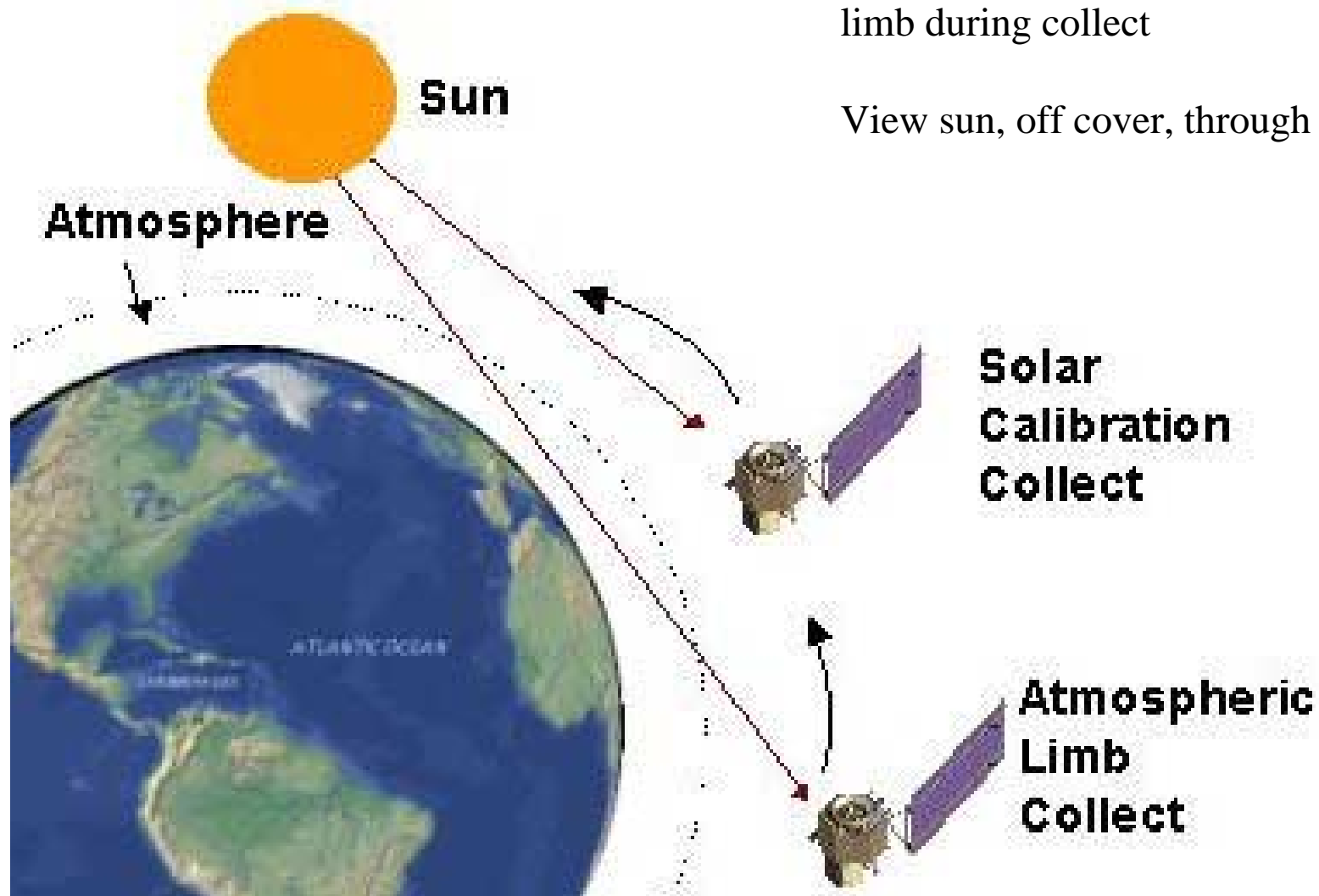>
> *spectral features spanned SWIR, in VNIR*

Following to present:

> *description of collect, and data analysis technique and verification of VNIR and SWIR spectral calibration*
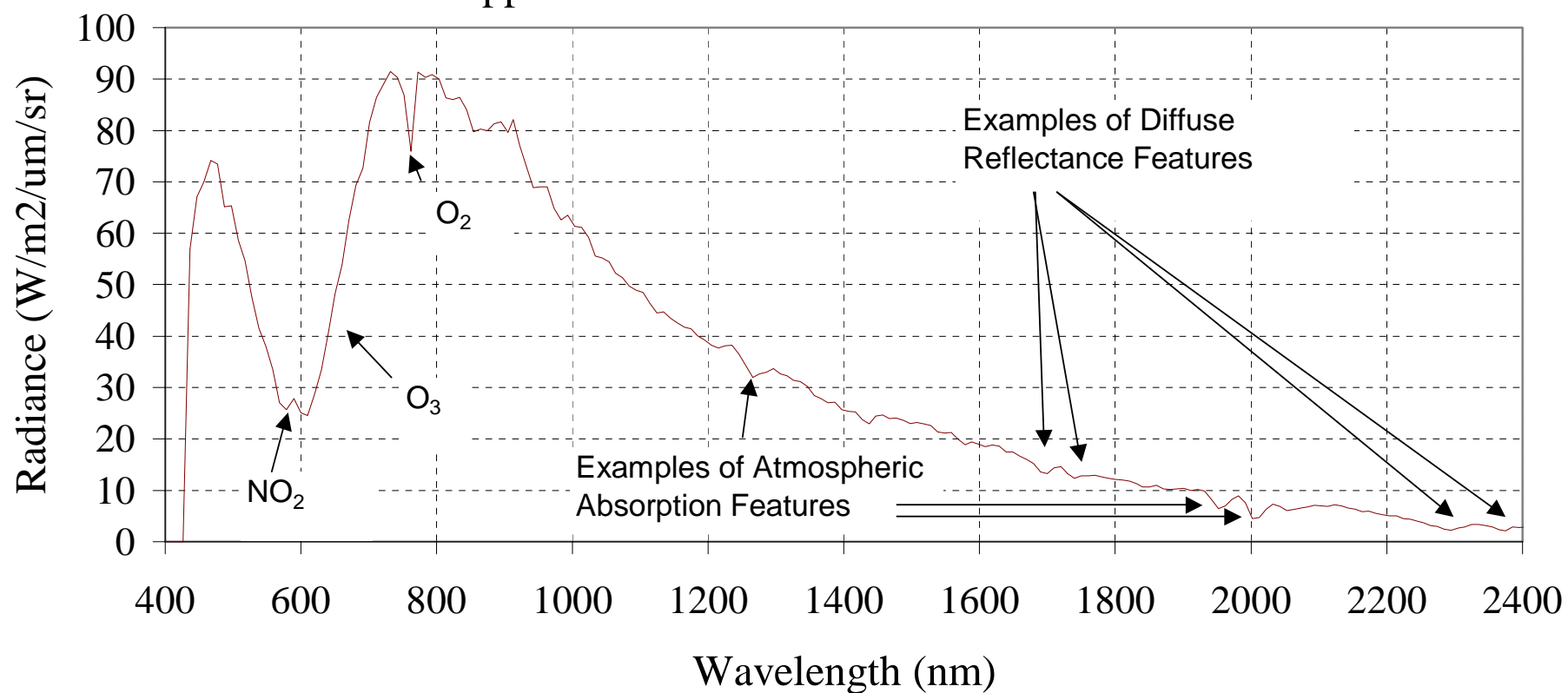
Hyperion Spectral Calibration

Early solar cal, sun is rising through earth's limb during collect

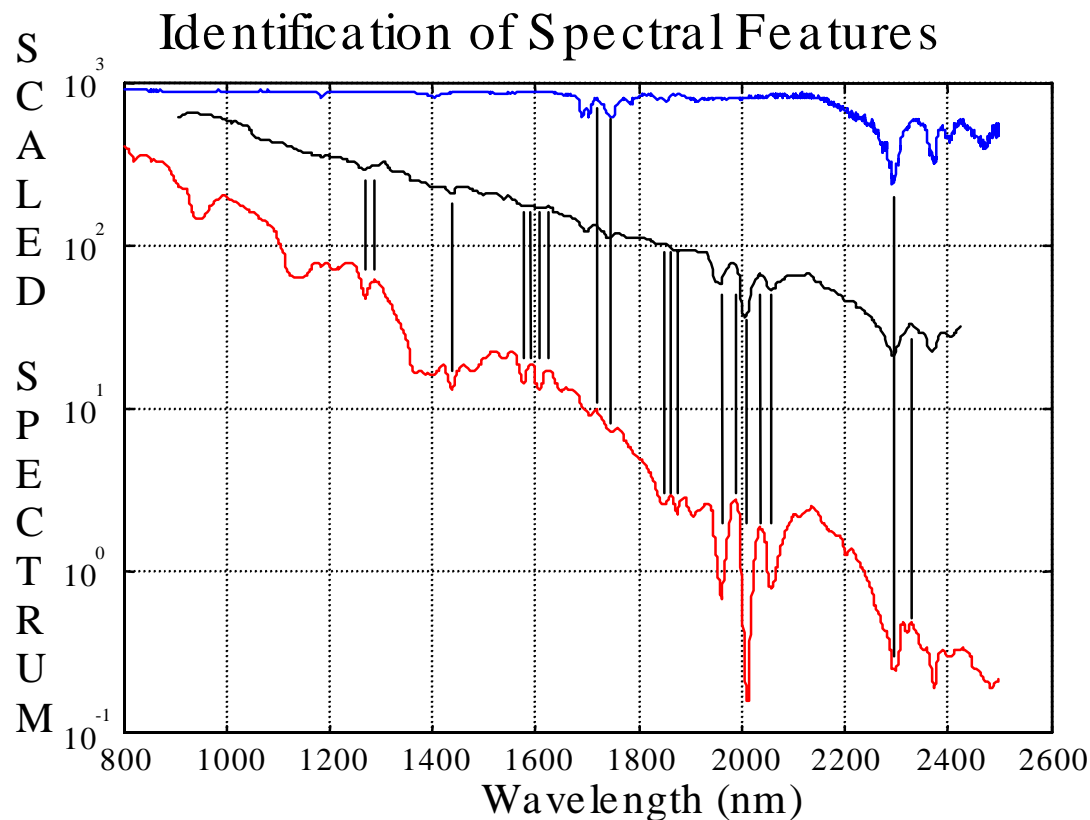View sun, off cover, through atmosphere

Atmoshperic Limb Sample Spectra for the VNIR and SWIR
Approximate Identification of Features

Examples of Diffuse
Reflectance Features

O₂

O₃

NO₂

Examples of Atmospheric
Absorption Features

Radiance (W/m2/um/sr)

Wavelength (nm)

Spectral Calibration –SWIR

Identification of Spectral Features

Plot axis — Y: SCALED SPECTRUM, 10^3, 10^2, 10^1, 10^0, 10^{-1}; X: Wavelength (nm), 800 1000 1200 1400 1600 1800 2000 2200 2400 2600

Hyperion Spectra of Atmospheric Limb Collect – red

Atmospheric Reference Profile from Modtran 3 – black

Cary 5 & FTS measured Diffuse Cover Reflectance – blue

Process:

1.) Create Pseudo-Hyperion Spectra from reference: *Modtran-3 for atmosphere, and Cary 5 & FTS measurements for diffuse reflectance of the cover*

2.) Correlate Spectral Features: *band number units of Hyperion max/min correlated with reference wavelength of max/min*
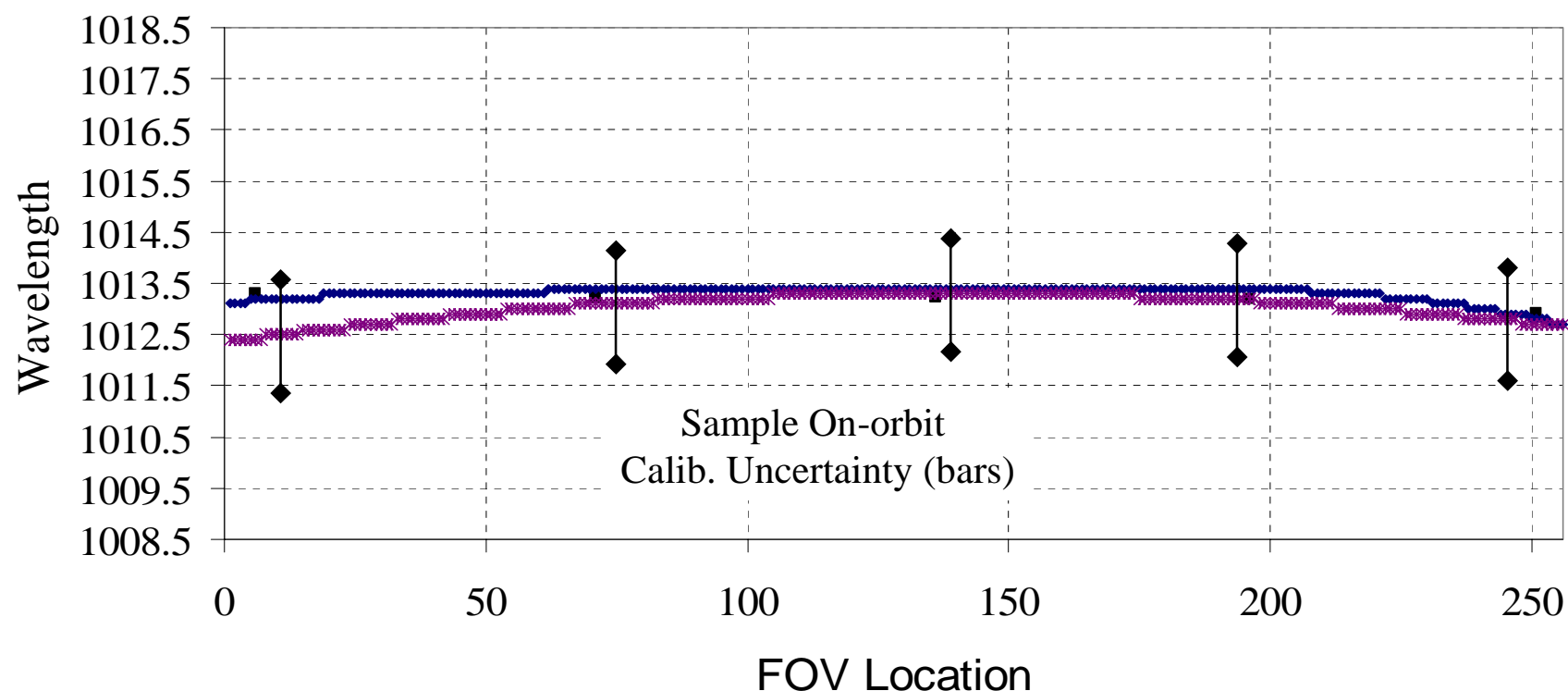
3.) Calculate Band to Wavelength map: *apply low order polynomial to fit the data over the entire SWIR regime*

Calibration Comparison: SWIR

SWIR Comparison of Spectral Calibration: Spectral Band 87

■ Pre-Flight Points   ◆ Pre-FLight Calibration   —✳— On-Orbit Calibration
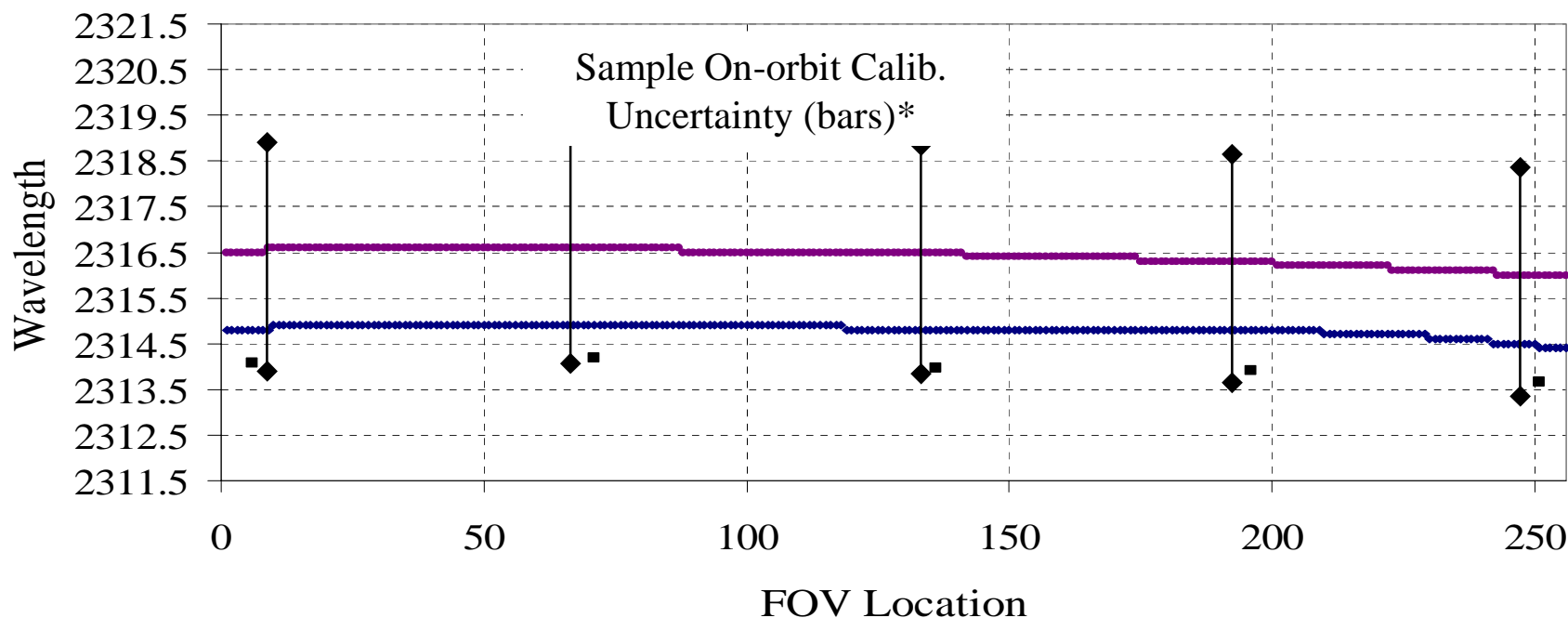

Accuracy assessment: accuracy of diffuse reflectance reference spectrum < 1 nm

accuracy of analysis method +- 1 nm

Calibration Comparison: SWIR

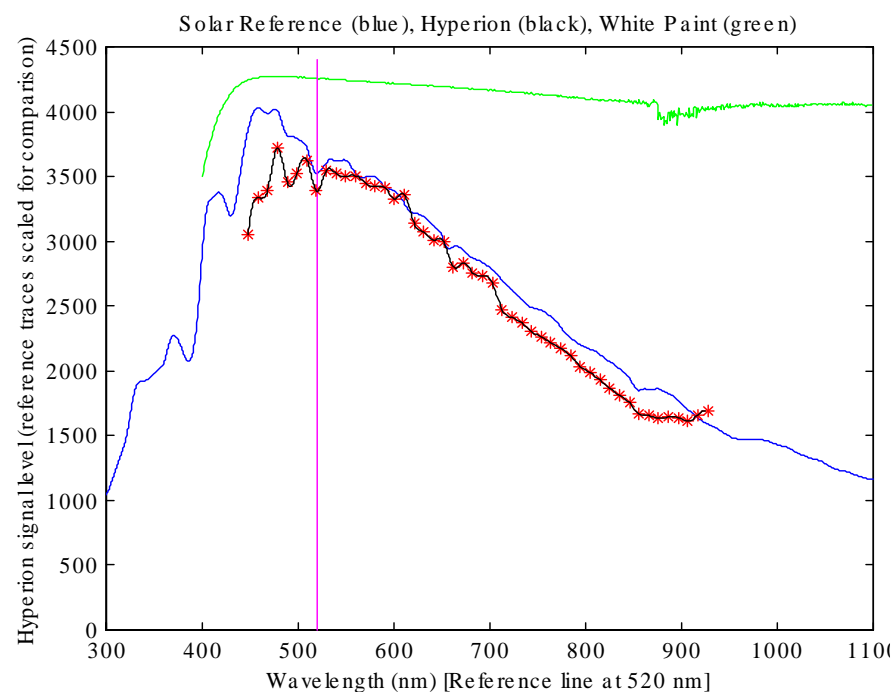SWIR Comparison of Spectral Calibration: Spectral Band 216

■ Pre-Flight Points • Pre-Flight Calibration ⊷ On-Orbit Calibration

Accuracy assessment: accuracy of the atmospheric absorption reference spectrum, +-2.5 nm

accuracy of analysis method +- 1 nm
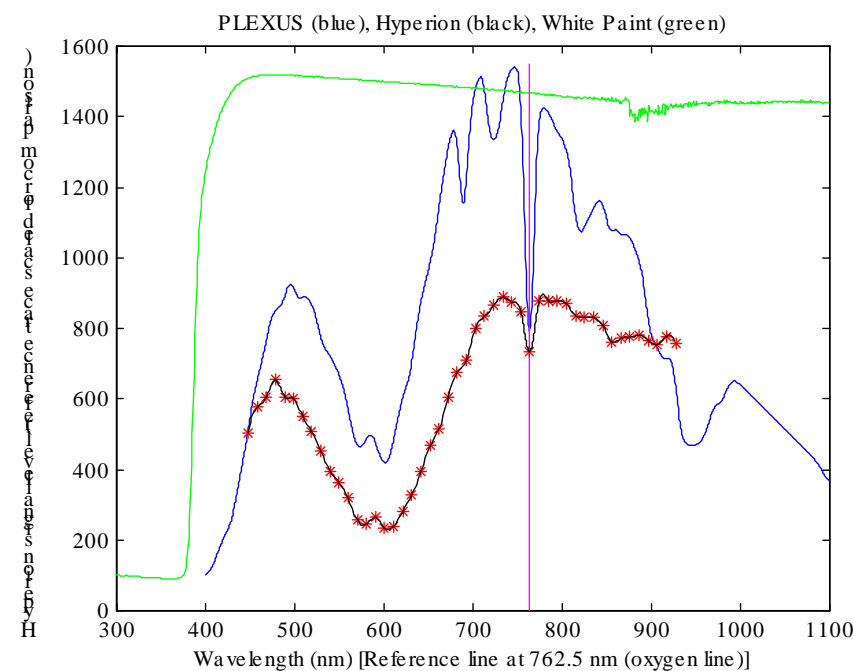
VNIR Spectral Calibration: Solar & Oxygen

Solar Reference (blue), Hyperion (black), White Paint (green)

SOLAR LINE
Hyperion Data (red)
Solar Reference (blue)
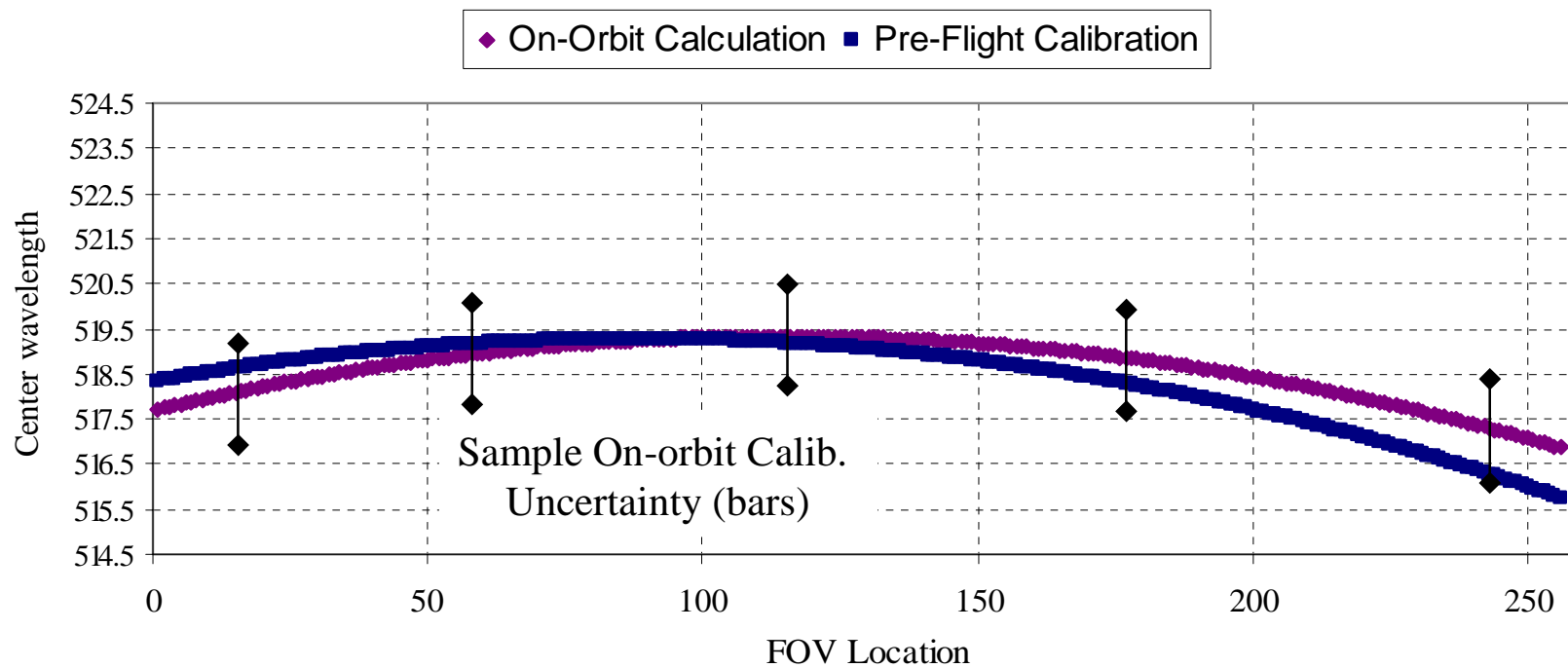White Paint Transmission (green)

PLEXUS (blue), Hyperion (black), White Paint (green)

OXYGEN LINE
Hyperion Data (red)
PLEXUS Calculation (blue)
White Paint Transmission (green)

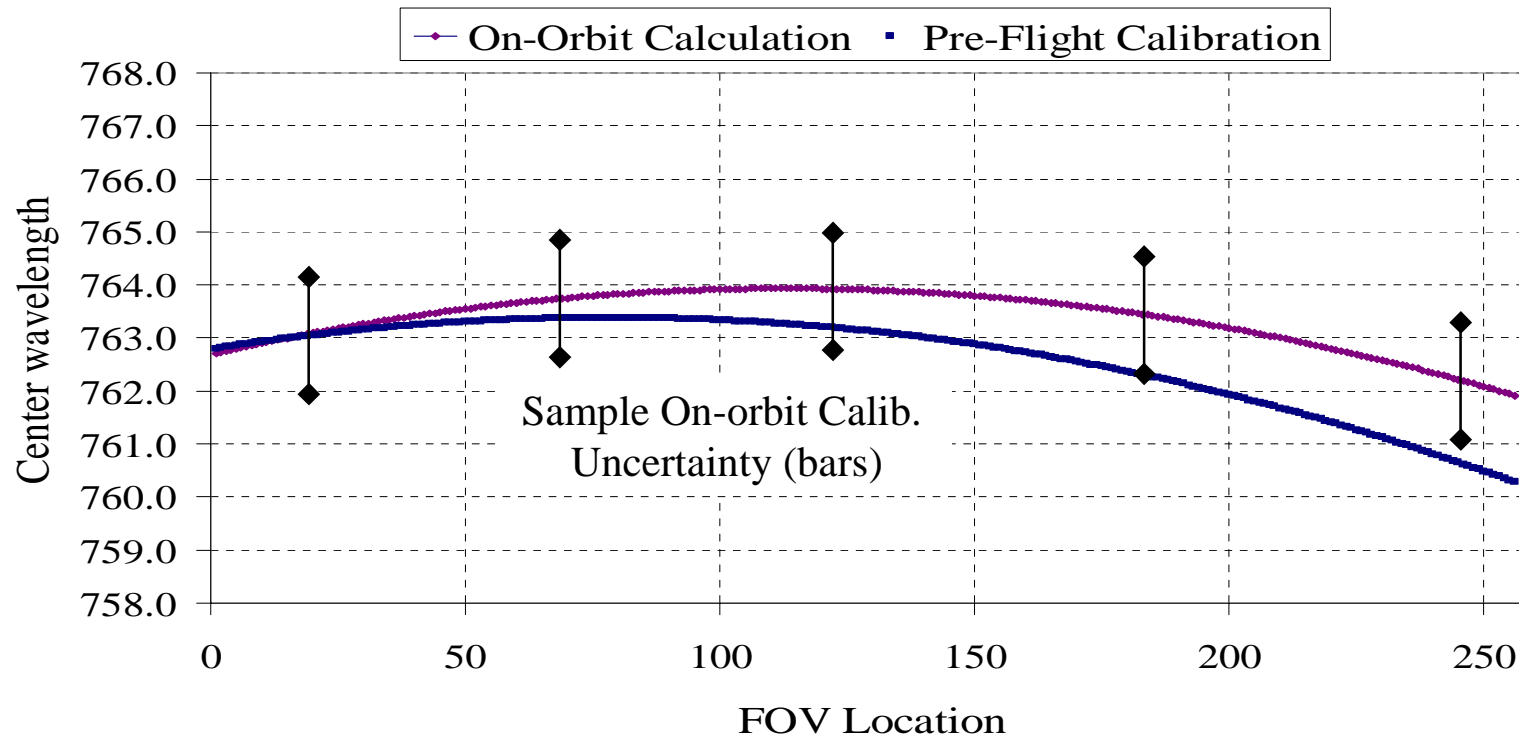# Calibration Comparison: VNIR

VNIR Comparison at Spectral Channel 17

Accuracy assessment: accuracy of the solar reference spectrum, +-1 nm

accuracy of analysis method +- 1 nm

VNIR Comparison at Spectral Channel 41

Accuracy assessment: accuracy of the atmospheric oxygen reference spectrum, +-1 nm

accuracy of analysis method +- 1 nm

NOTE: offset and rotation applied to pre-flight calibration file to match reference

Spectral Comparison

Technique used to verify center wavelength for VNIR and SWIR focal plane

> *Verification wavelength dependent, ranges from +- 1 nm to +-2.5 nm.*

> *Accuracy dependent on reference spectrum and analysis method*

Results used to verify no change in VNIR and SWIR dispersion:

> *VNIR: 10.18 nm/pixel pre-flight (compared to) 10.19 nm/pixel on-orbit*

> *SWIR: 10.09 nm/pixel pre-flight (compared to) 10.09 nm/pixel on-orbit*

Results used for verify cross-track spectral error:

> *VNIR: 2.8 to 3.6 pre-flight (compared to) 1.7 to 2.55 on-orbit*

> *SWIR: < 1nm pre-flight (compared to) < 1 nm on-orbit*

Conclusions

Developed on-orbit technique based on atmospheric limb collect

    strength was the absorption features of the diffuse reflectance of white paint

    current largest source of errors associated with: reference atmospheric profile related to knowledge of cut through the atmosphere

On-orbit verification of SWIR center wavelength, cross-track spectral error measurement, dispersion measurement all agree with pre-flight measurements and requirements

VNIR spectral calibration verification performed using combination of Oxygen line (762.5 nm) from atmospheric line and Fraunhoffer line (520 nm) visible in solar calibration collect.